

IMPLICIT HYDRODYNAMICS FOR COOKOFF PROBLEMS

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High explosive (HE) cookoff refers to experiments in which a cylindrical HE charge is confined by a cylindrical steel confinement, then subjected to an external heat source. This heat source causes the HE to slowly expand, begin chemical reactions, and eventually begin burning. This physical process takes place over a large range of timescales – hours for the HE thermal expansion, to fractions of a microsecond for the HE burn. Simulating physical events that take place over long time scales is the motivation for the implicit hydrodynamics package in ALE3D.

Implicit hydrodynamics is not subject to the Courant stability constraint that prevents explicit hydrodynamics from being a viable option for these calculations. The challenge presented by these methods is the need to solve large linear systems of equations. ALE3D has adopted a non-linear, fully implicit displacement formulation for its implicit hydrodynamics. This means that each time step, the hydrodynamic equilibrium equations are linearized, creating a matrix equation for the nodal displacements of the finite element mesh. Inertial terms are included via a Hilber-Hughes-Taylor operator. A Newton-Raphson loop surrounds these linear solves, and is iterated until nodal displacement corrections and forces converge. Recent additions to our arsenal of matrix solvers have allowed us to solve very large parallel problems.

Sliding interfaces introduce additional complexity to implicit hydrodynamics. They are necessary for the cookoff modelling because there are air gaps between the HE charge and the steel confinement that close during the thermal expansion phase of the problem. We have experimented with several methods for handling slide surface constraints. Our traditional method constrained the nodes on one side of the surface to the other side with a Lagrange multiplier. Recently, our slide surface constraints have been improved to use an augmented Lagrangian method. This provides a more robust framework for handling void opening and closure and friction. These constraints also add additional challenges to the linear solvers, which will be discussed.

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